Printed Multi-Band MIMO Antenna Systems: Techniques and Isolation Mechanisms

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جامعـــــة الملـك فهـــد للبتـــرول والمعـــــــــادن
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PRESENTATION SCOPE

- Why MIMO antenna systems?
- Multi-Band printed MIMO Antenna Structures
- Multi-band Isolation Mechanisms for Printed MIMO antennas
- Results and Discussions
- Conclusions

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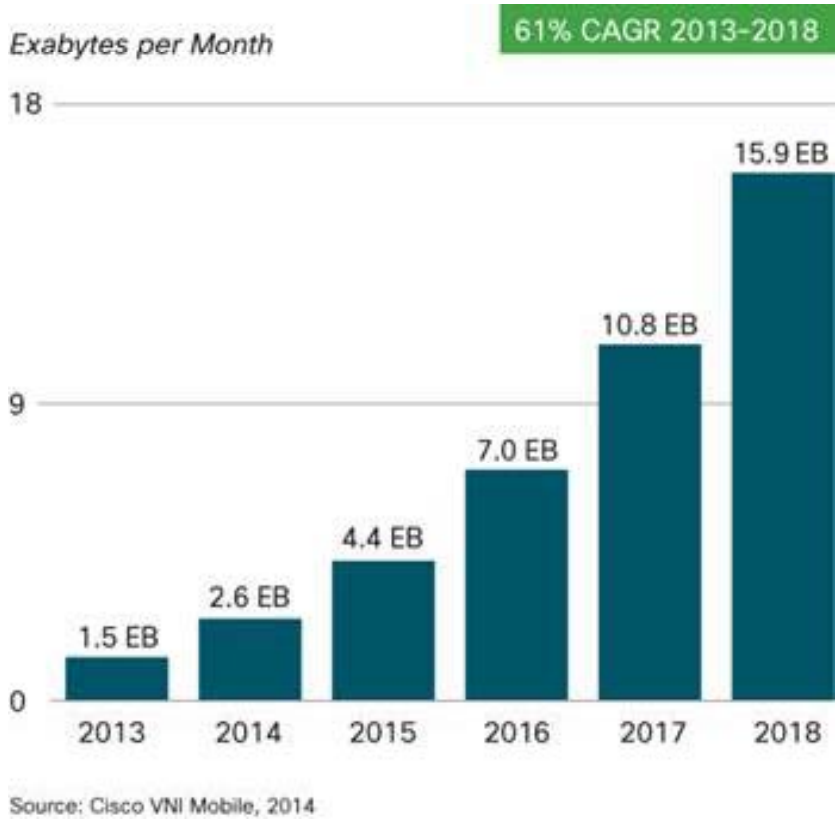
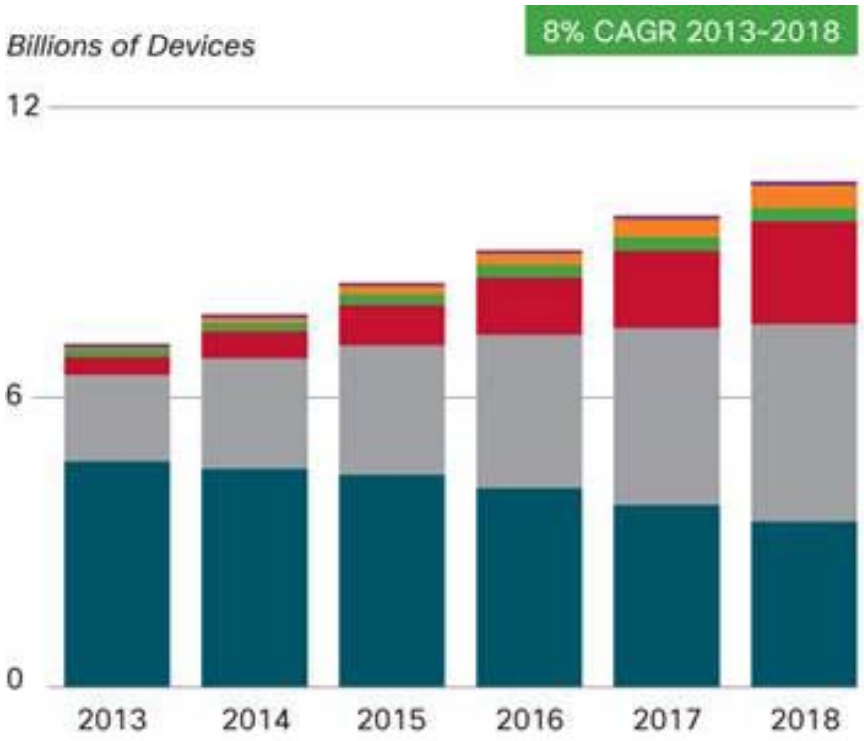
WHY MIMO?

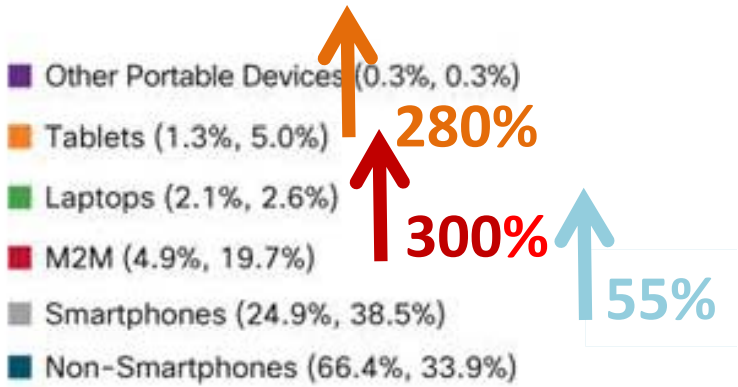
- **From a very recent report from CISCO:**
  - 10.6 times increase in 5 years
  - Compound annual growth rate (CAGR) of 61% per year
  - All portable and smart phone devices are dominating the market and the traffic



[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018, Feb. 2014.



Figures in parentheses refer to device or connections share in 2013, 2018.
Source: Cisco VNI Mobile, 2014



By the end of 2014, the number of mobile-connected devices will exceed the number of people on earth!

- **To achieve such increase in the data rates in the user terminals, several enabling technologies are considered in 4G / 5G systems:**
  - Use of Multiple-input-multiple-output (MIMO) systems and Beam-Forming
  - Use of Advanced Modulation and Coding schemes (AMC)
  - Use Multiple Access Techniques
  - Use of smaller cells
  - Device to Device communications
  - Use of MM-waves

MIMO ADVANTAGE

- If M_T is the number of transmitting antennas, N_R is the number of receiving antennas, W is the channel bandwidth in Hz and SNR is the average signal to noise ratio at the receiver, then the channel capacity is given by equation:

$$C = BW \log_2 \left(1 + M_T \times N_R \times SNR\right) \quad \text{bits/s} \qquad (1)$$

- This can be considered as an M_T x N_R times increase in the SNR which results in an increase in channel capacity.

- **Placing antennas in close proximity will degrade the MIMO advantage due to coupling and signal correlation**
- **See Figures from left to right, placing antennas closer together at the Tx and Rx clearly degrades the data throughput.**

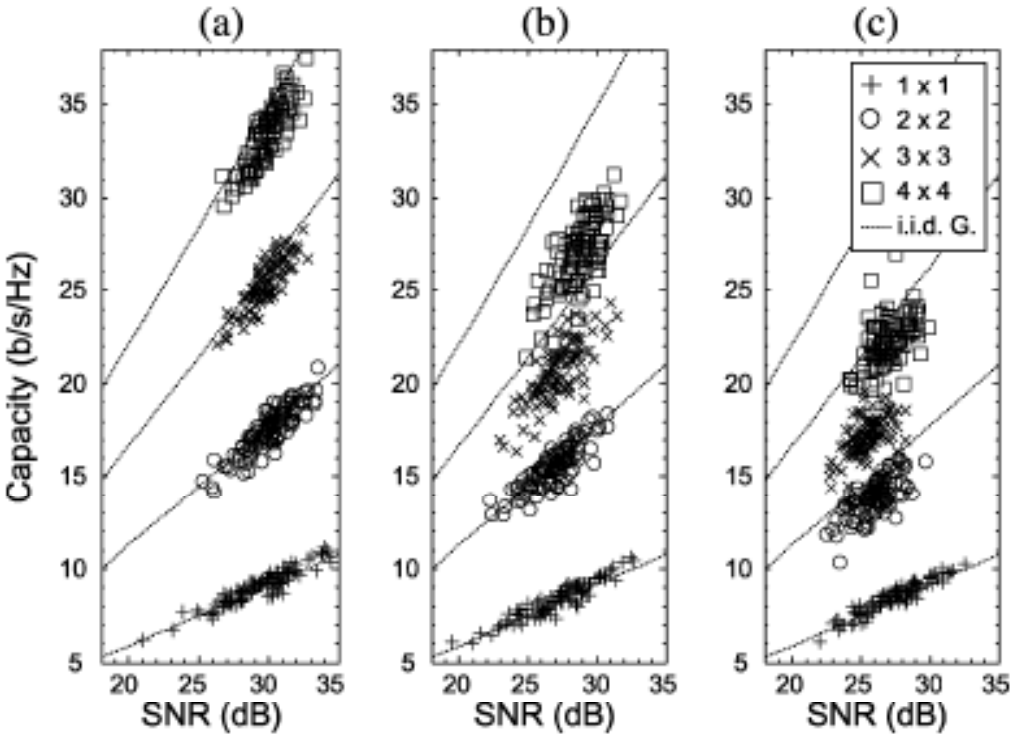


Fig. 11. Measured channel capacity for $\{L \times L | L \in [1, 2, 3, 4]\}$ MIMO cases with dipole arrays for which the dipole separations, denoted $(\Delta_d^{(TX)}, \Delta_d^{(RX)})$, were (a) (λ, λ), (b) $(\lambda/8, \lambda)$, and (c) $(\lambda/8, \lambda/8)$.

[2] D. W. Browne, M. Manteghi, M. P. Fitz, and Y. Rahmat-Samii, "Experiments with compact antenna arrays for MIMO radio communications," *IEEE Trans. Antennas Propag., vol. 54, no. 11, pp. 3239–3250,* Nov. 2006.

WIRELESS STANDARDS UTILIZING MIMO (CURRENT AND FUTURE?)

Application	Wireless Standards	Frequency Bands (MHz)	Number of MIMO antennas at UE
Smart phones / tablets	LTE , LTE-A,	700 – 2,600 (multiple bands)	2 / 4
	802.11n,	2,450 / 5,800	2 / 4
Laptops /PCs	802.11ac,	5,200	2 / 4 / 8
	802.16m,	2,300 / 2,500 / 3,500	2
USB dongles	802.11ad,	60,000	4 / 8 / ?
V2V	DSRC	5,900	
	802.11aj	45,000 / 60,000	
	?	30,000	

→ **Multi-band and Multi-antenna systems are essential!**

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PRINTED MULTI-BAND MIMO ANTENNAS

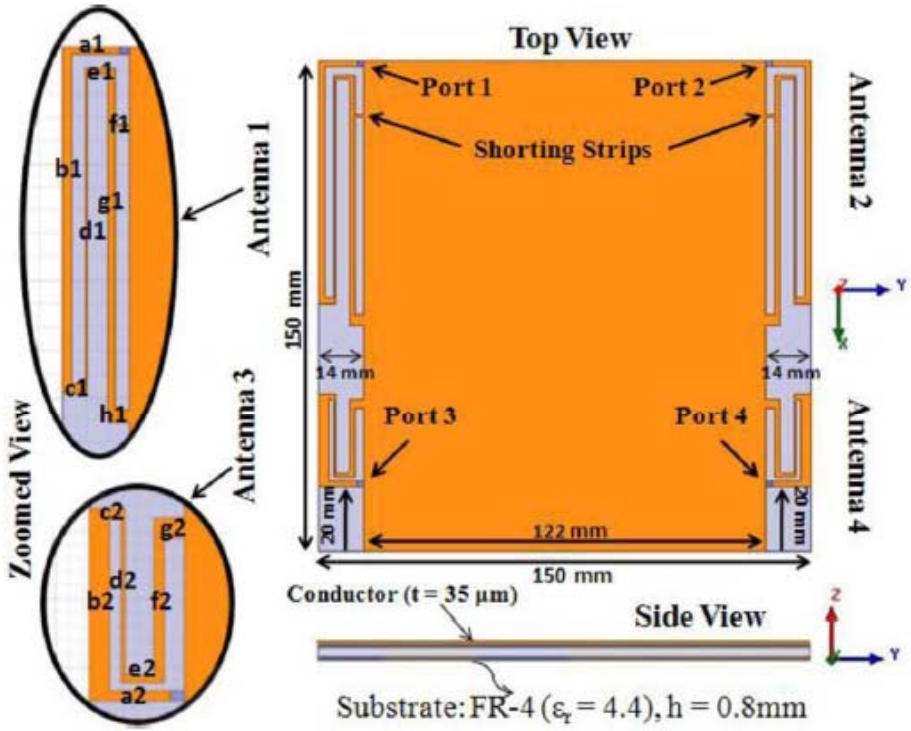
- **Several multi-band techniques for printed antennas are widely used in literature,**
  - Shorting pins
  - Introducing slots within the radiating element
  - Multi-arm use or integrating multi-elements
  - Coupling with parasitic elements
  - Antenna loading with exotic materials (MTM, MD, etc)
  - Others …

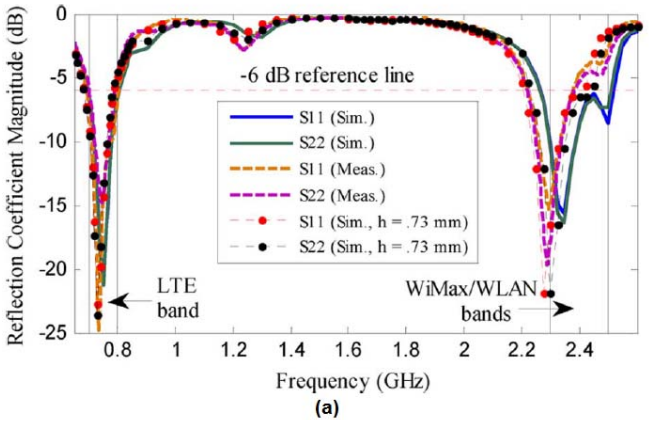
This table is for demonstration of majority of work that appeared in literature, some other types also exit

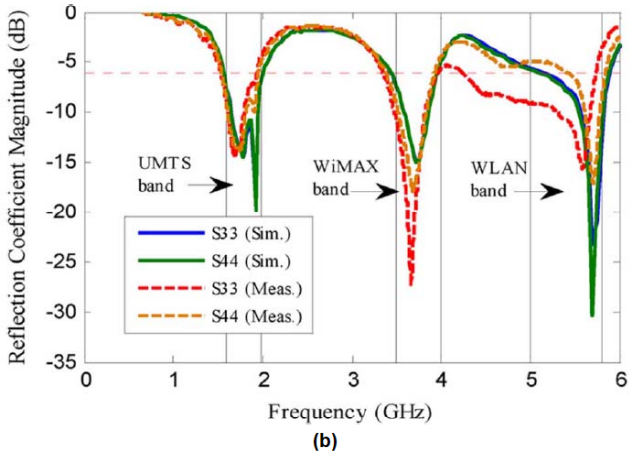
	Below 1 GHz	Above 1 GHz
Multi-Band Antenna Types	Inverted-F (3D)	Inverted-F (3D)
	Loops	Loops
	PIFA / Modified PIFA	Meanderlines
	Folded / Modified Dipoles	Monopoles
	Folded / Modified Monopoles	Modified dipoles
	Magneto-Dielectric loaded (3D)	MTM inspired
	Ceramic loading (3D)	Modified patches

- **Some recent Multi-Band Printed MIMO examples:**

1



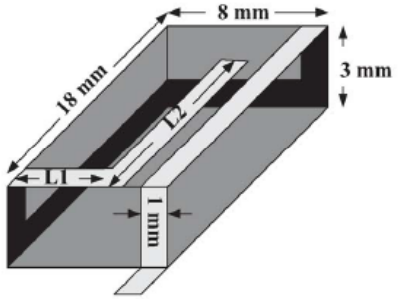




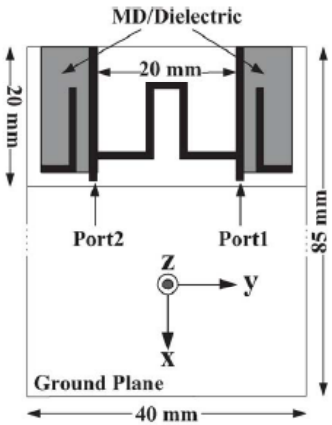
Large back plane suitable for Wireless Routers and large access points

[3] S. C. Fernandez and S. K. Sharma, "Multiband Printed Meandered Loop Antennas With MIMO Implementations for Wireless Routers," *IEEE Antennas and Wireless Propagation Letters*, Vol.12, pp. 96-99, 2013.

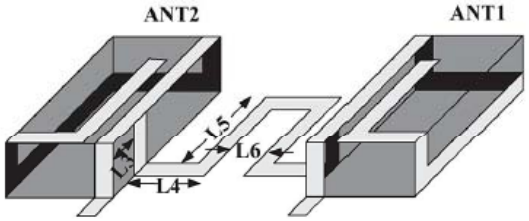
2



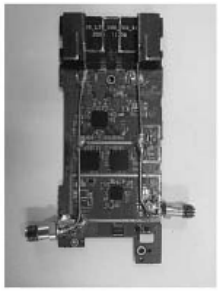
(a)



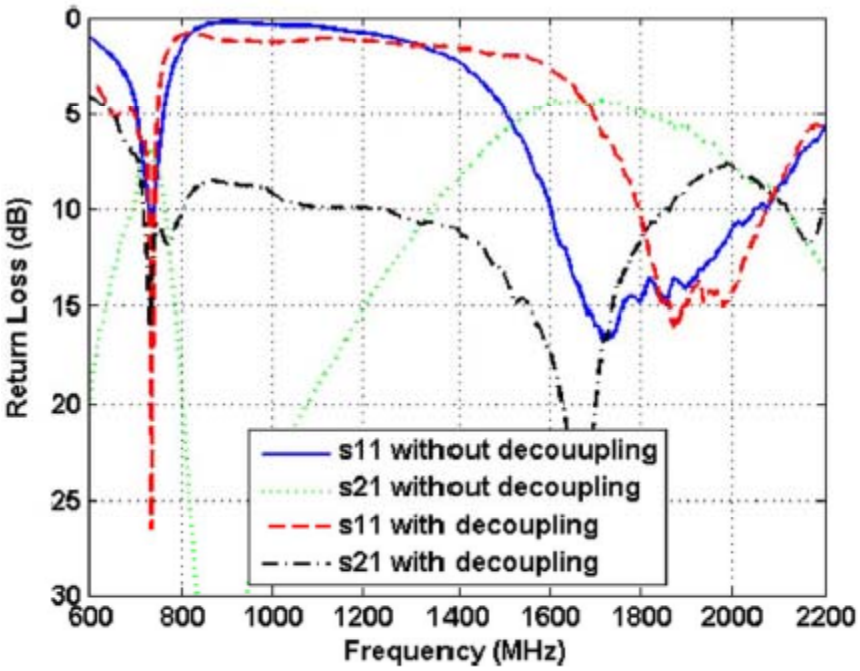
(b)



(c)



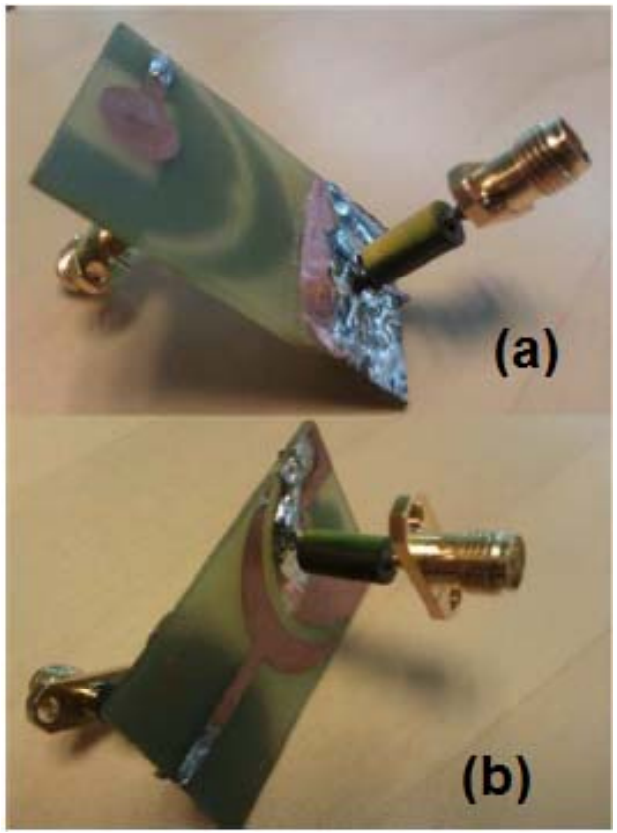
(d)

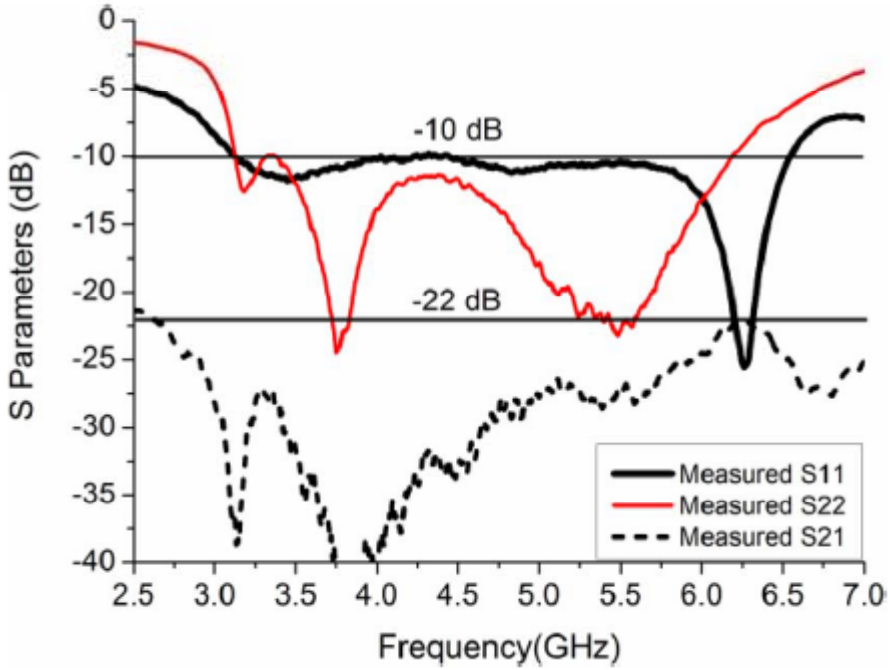


Cell Phone size plane suitable for handheld devices and cell phones

[4] Y. Chen, J. Lee and J. Lee, "Quad-Band Monopole Antenna Including LTE 700 MHz With Magneto-Dielectric Material," *IEEE Antennas and Wireless Propagation Letters*, Vol.11, pp.137-140, 2012.

3





Very small back plane suitable for USB Dongles

[4] S. Zhang, B. K. Lau, A. Sunesson and S. He, "Closely-Packed UWB MIMO Diversity Antenna with Different Patterns and Polarizations for USB Dongle Applications," *IEEE Transactions on Antennas and Propagation*, Vol.60, No.9, pp. 4372-4380, September 2012.

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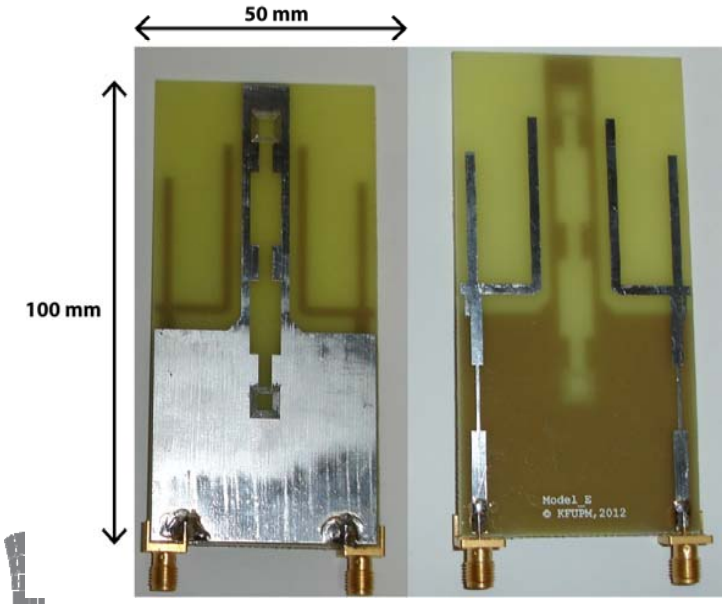
MIMO ANTENNA ISOLATION IMPROVEMENT METHODS

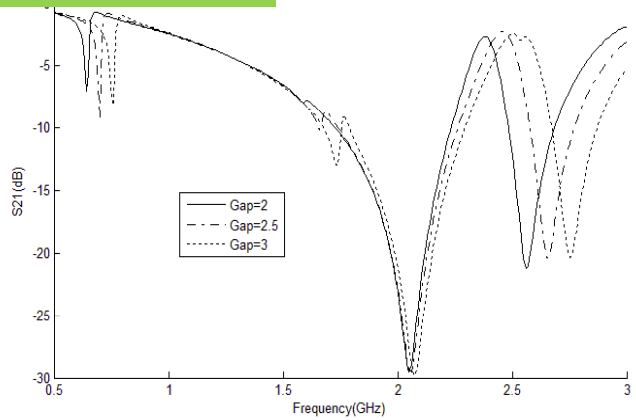
- **Extremely important for closely packed antenna systems (in handheld devices).**
  - Defected Ground Structures
  - Decoupling and lumped component structures
  - Neutralization strips
  - Introduction of resonating structures
  - Antenna orientation
  - Use of Metamaterials (MTM)

Almost all of these methods Work for single bands.

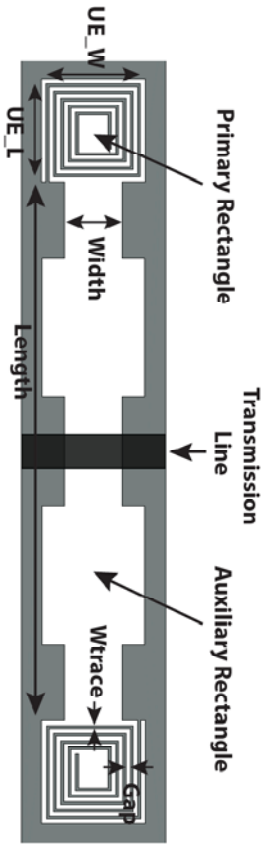
- **Recent Multi-band Isolation Examples**

Example 1: Defected Ground Structures

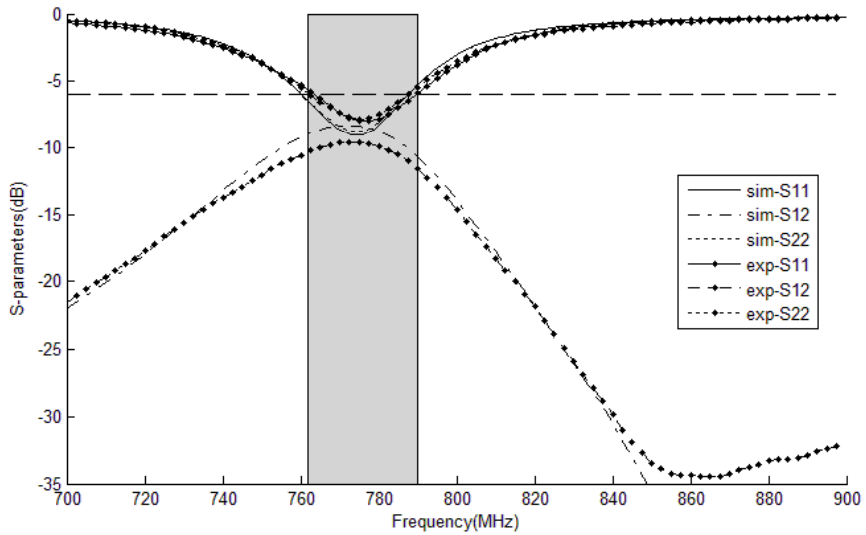




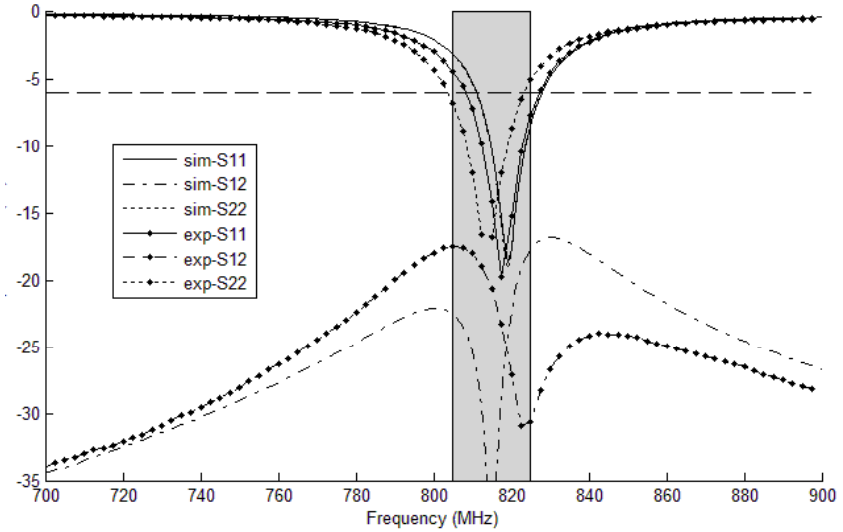
- DGS is acting as Dual-Band stop band filter
- Covering 800 MHz and 2.1GHz
- Low-Band frequency is controlled by dimensions of the spiral



[5] M. S. Sharawi, A. B. Numan, U. Khan and D. Aloi, "A Dual-Element Dual-Band MIMO Antenna System With Enhanced Isolation for Mobile Terminals," *IEEE Antennas and Wireless Propagation Letters*, Vol.11, pp. 1006-1009, 2012.



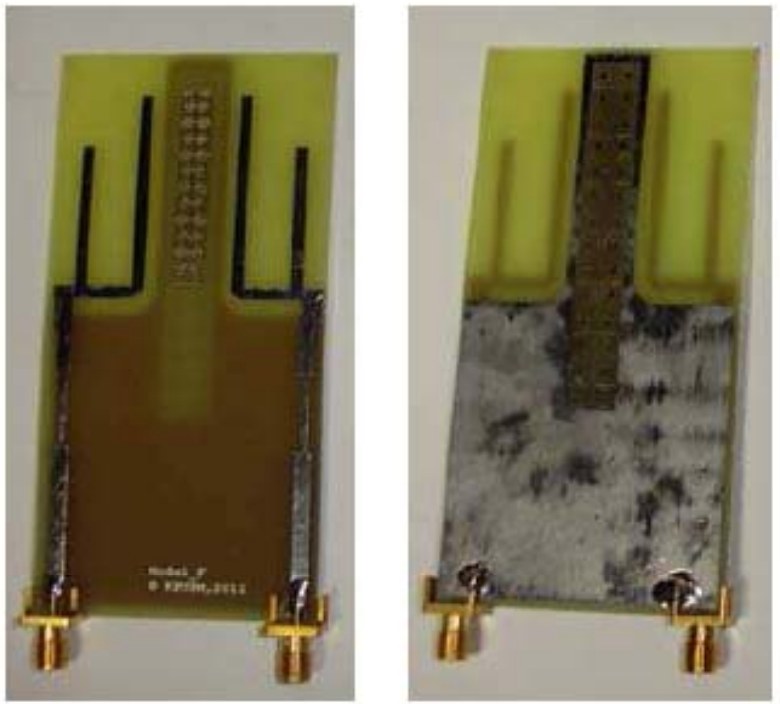
Reference Antenna
Bandwidth=762-790MHz

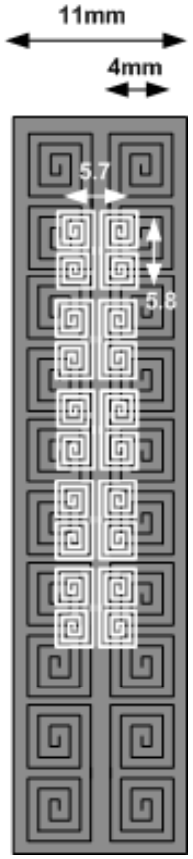


DGS
Bandwidth=805-825MHz

- Frequency is shifted due to DGS
- Bandwidth is reduced by approximately 8MHz
- Isolation is improved by more than 10dB

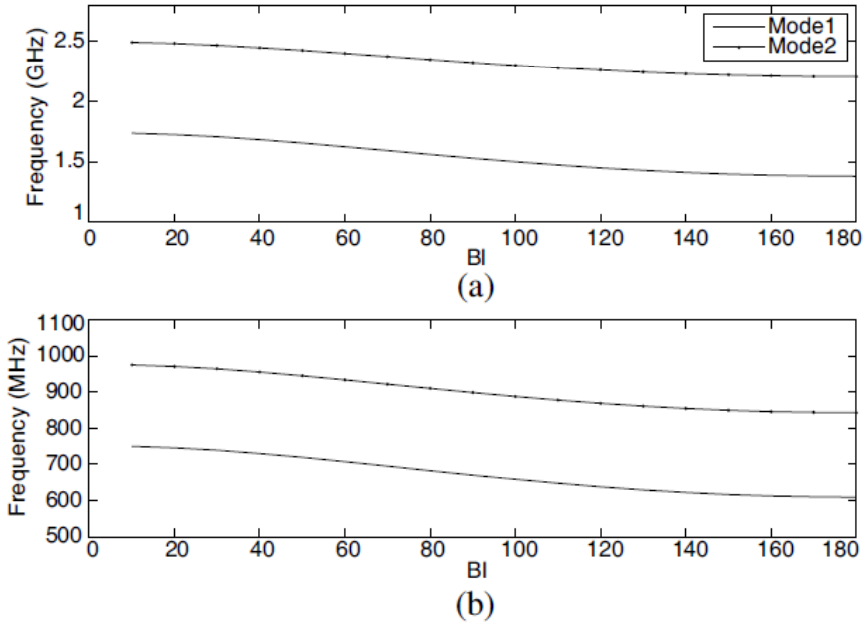
Example 2: Metamaterial based



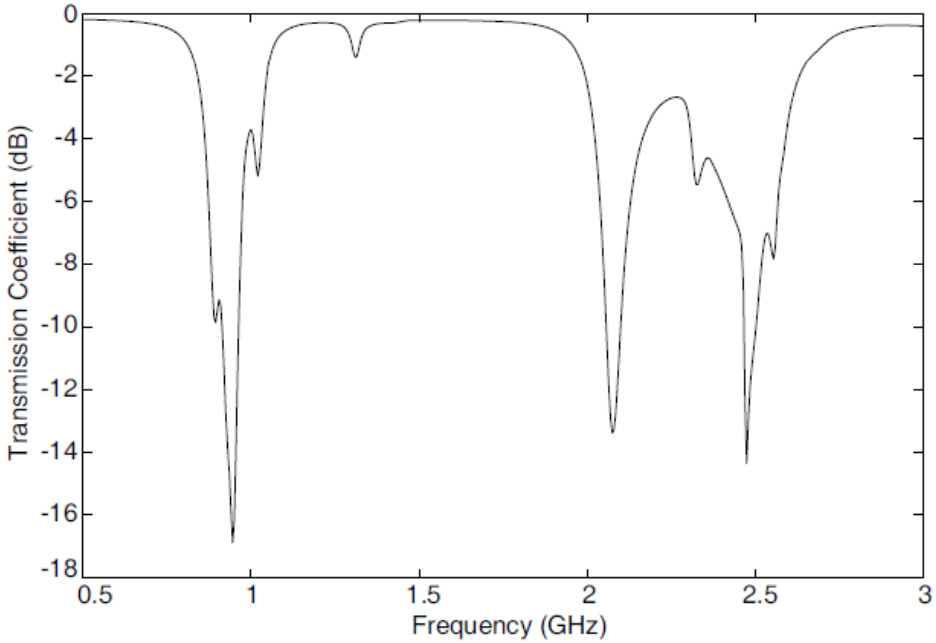


- CLLs were placed between the two antenna elements on TOP and BOTTOM Layers
- High-band is centered at approximately 2.6GHz
- Low-Band is centered at approximately 840MHz
- TOP layer CLL array isolates the higher band
- BOTTOM layer complementary CLL array isolates the lower band

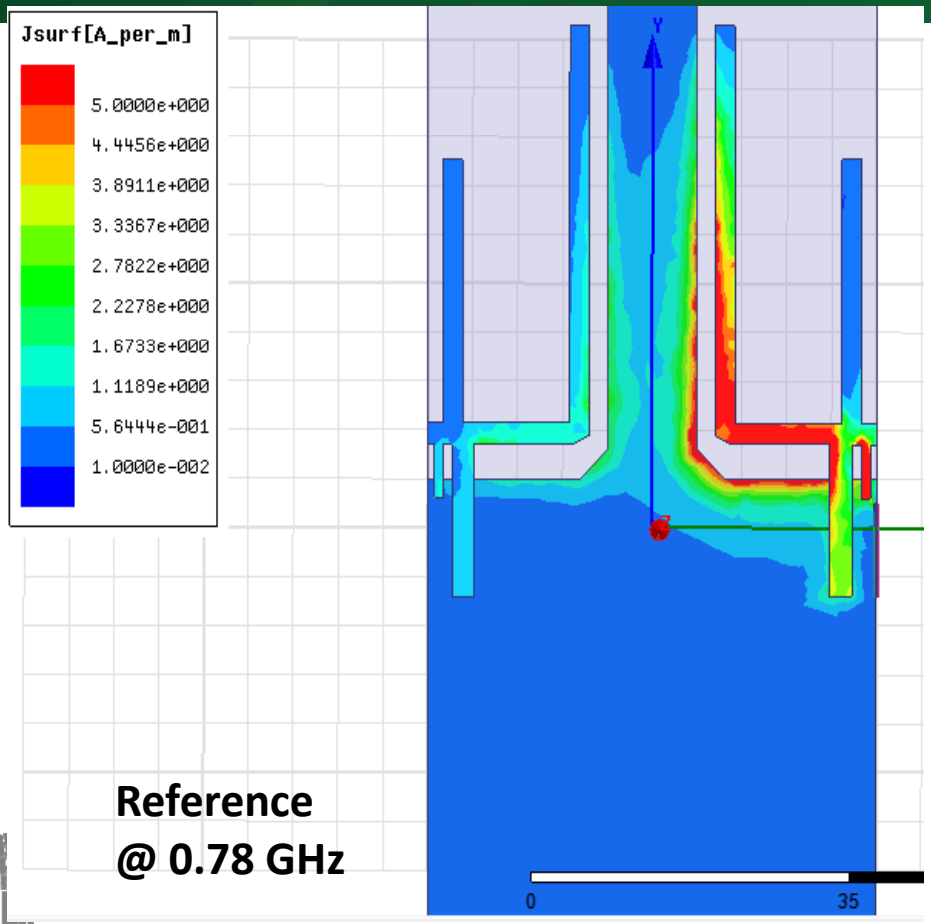
[6] M. S. Sharawi, A. B. Numan and D. Aloi, "Isolation Improvement in a Dual-Band Dual-Element MIMO Antenna System Using Capacitively Loaded Loops," Progress in Electromagnetic Research (PIER), Vol.134, pp. 247-266, 2013.



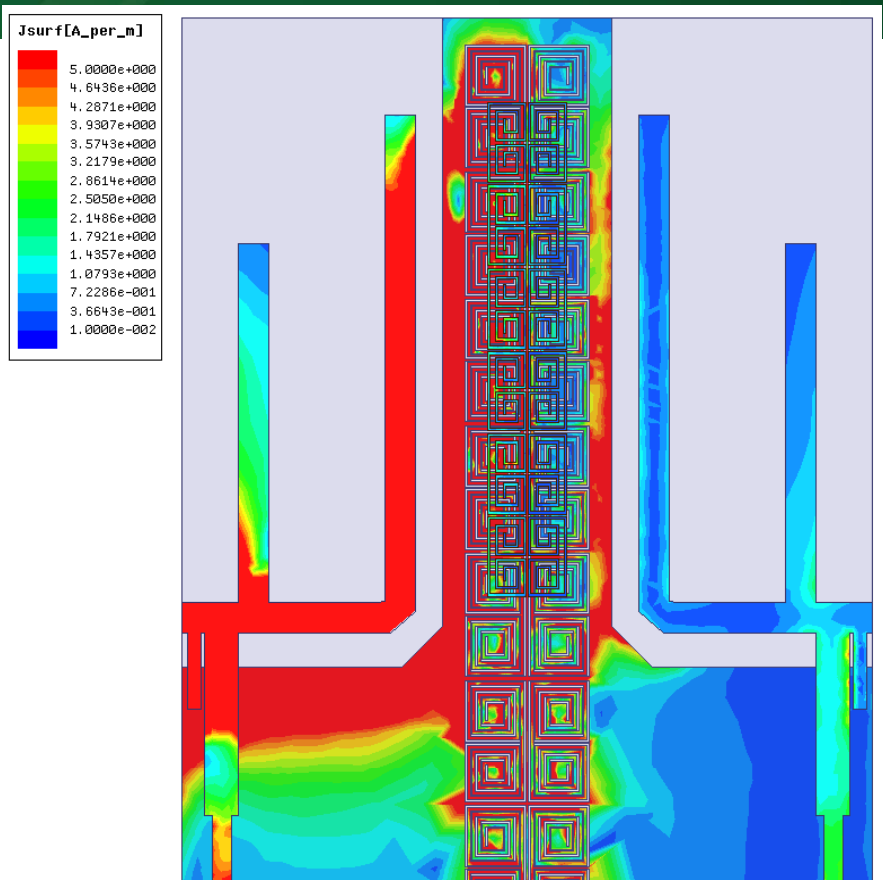
Dispersion Diagram for the (a) high band and (b) low band. This diagram shows the bandgaps where waves are suppressed, i.e. acting like a filter



Transmission Coefficient of the dual band CLL isolation enhancement structure

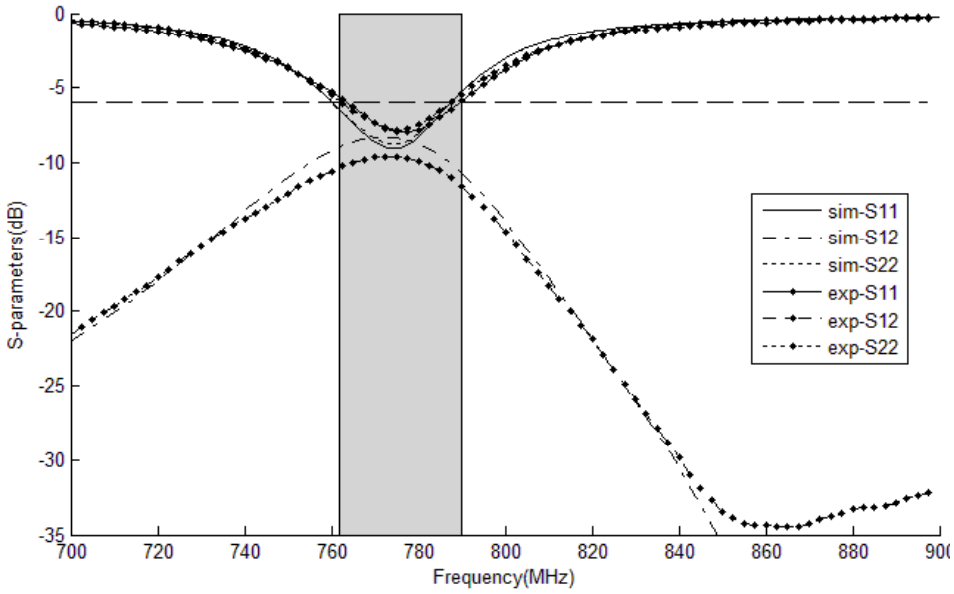


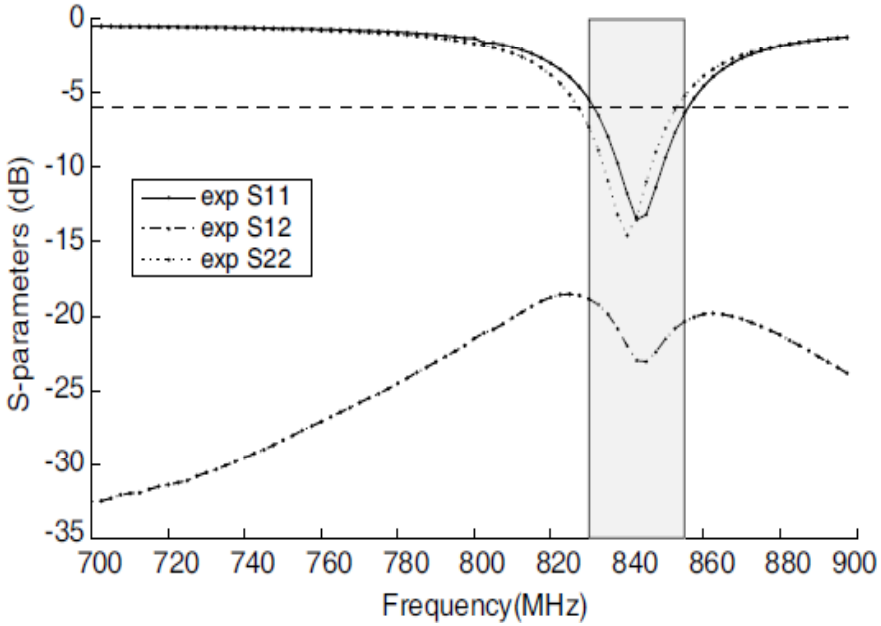
Reference
@ 0.78 GHz



Current Distribution with and without CLLs between two dual band antennas in a cell phone size back plane.

MTM CLL
@ 0.84 GHz





Reference Antenna
Bandwidth=762-790MHz

MTM CLL
Bandwidth=827-853MHz

Note the isolation enhancement due to the CLLs in the lower band, and the frequency shift in the response.

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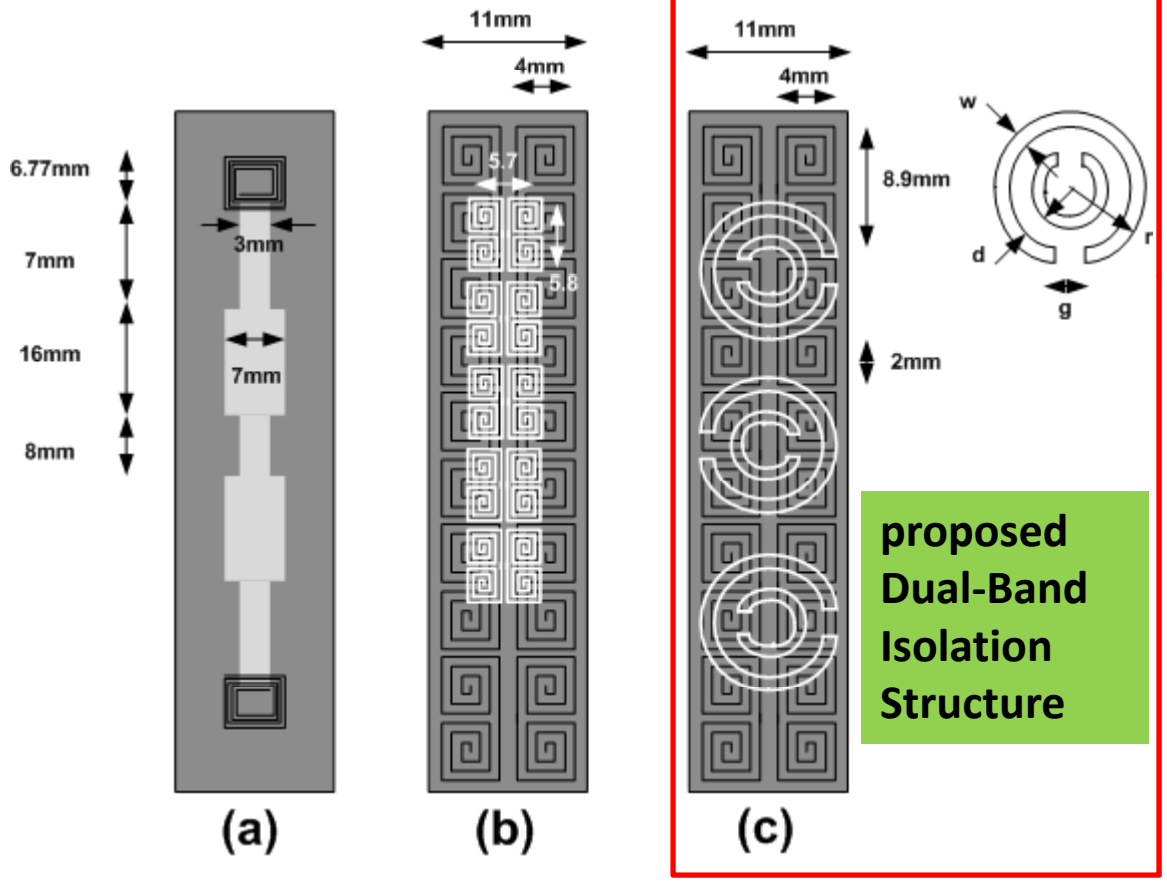
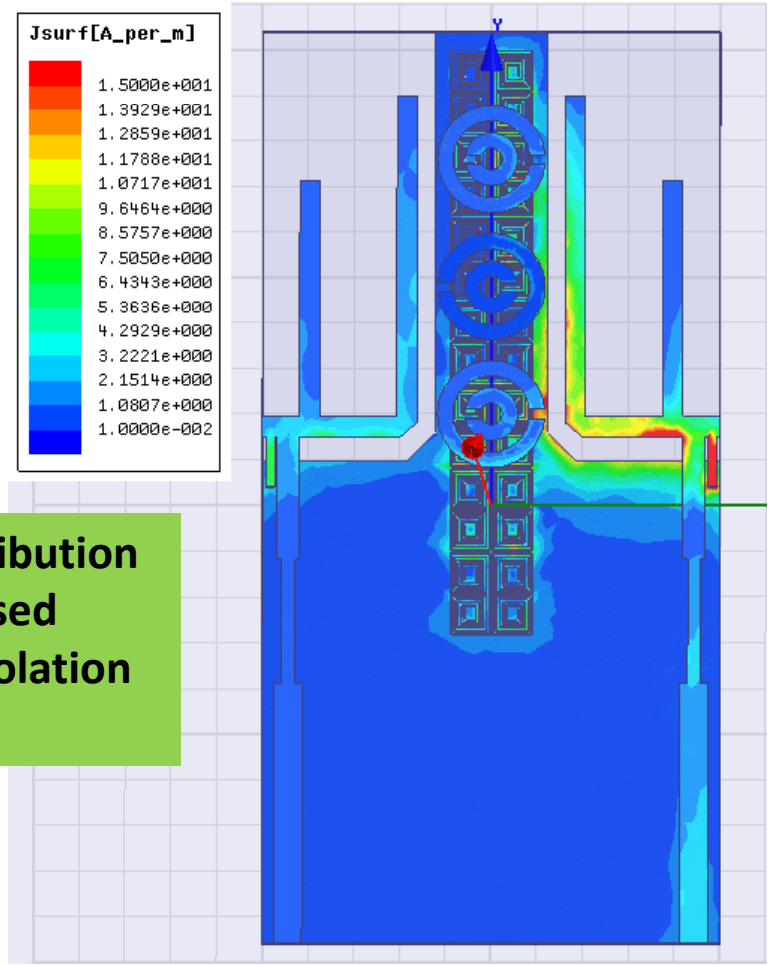
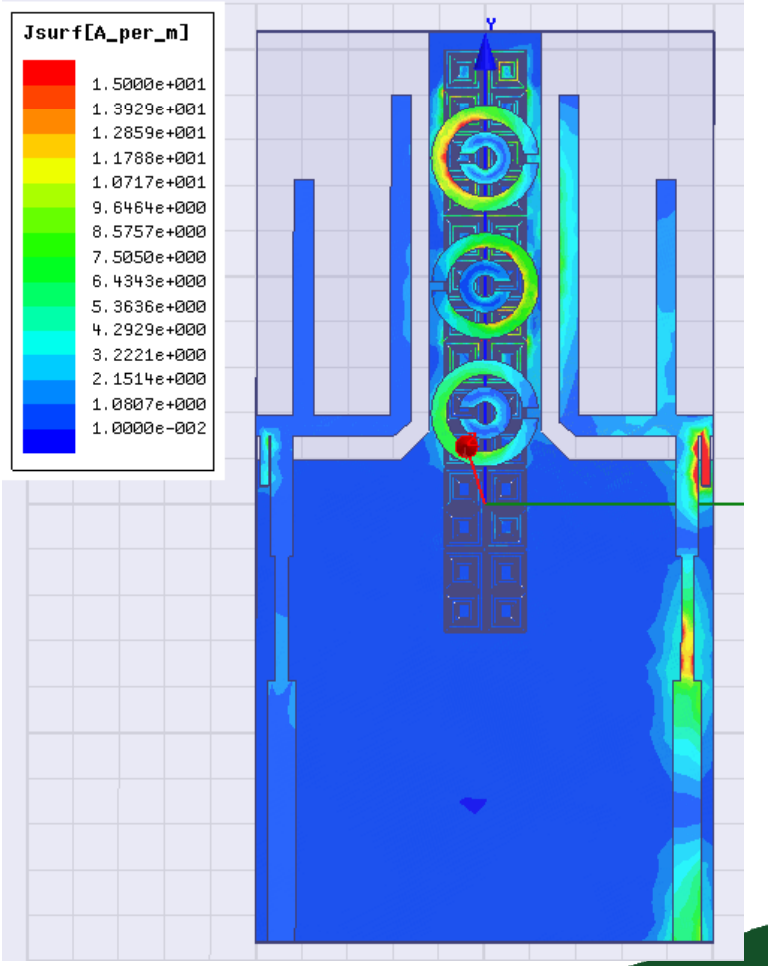
- An alternative dual band isolation enhancement method has been investigated combining CLLs and SRRs (case (c) in the Figure), and applied to the same reference design of dual-band 4-shaped antenna.



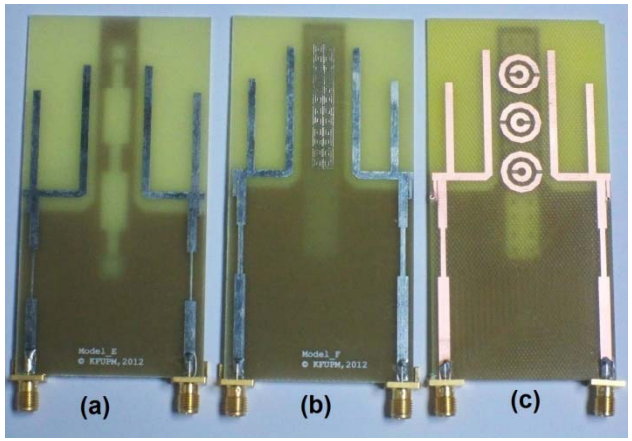
Current Distribution of the proposed Dual-Band Isolation Structure

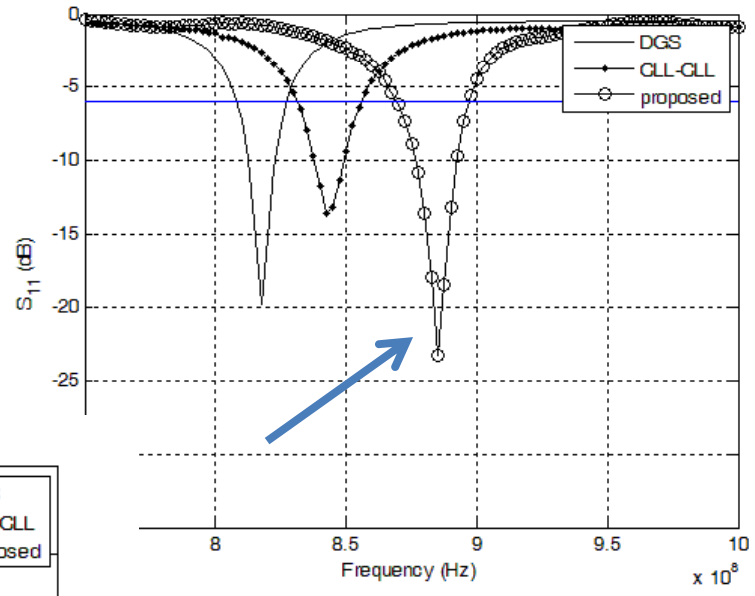


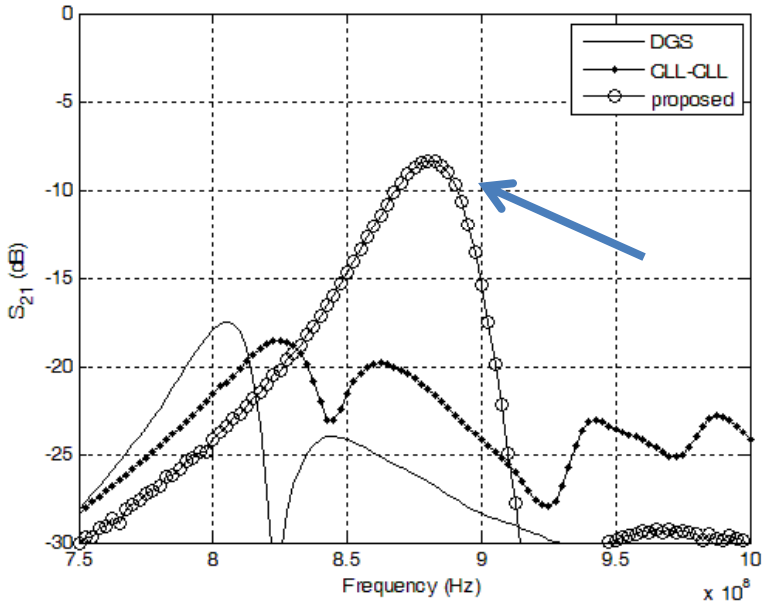
0.83 GHz



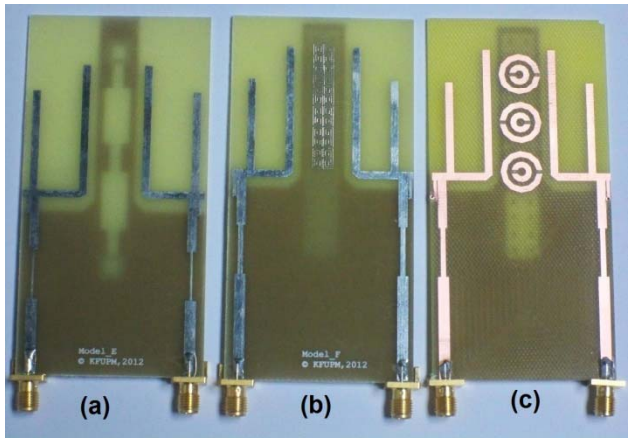
2.65 GHz

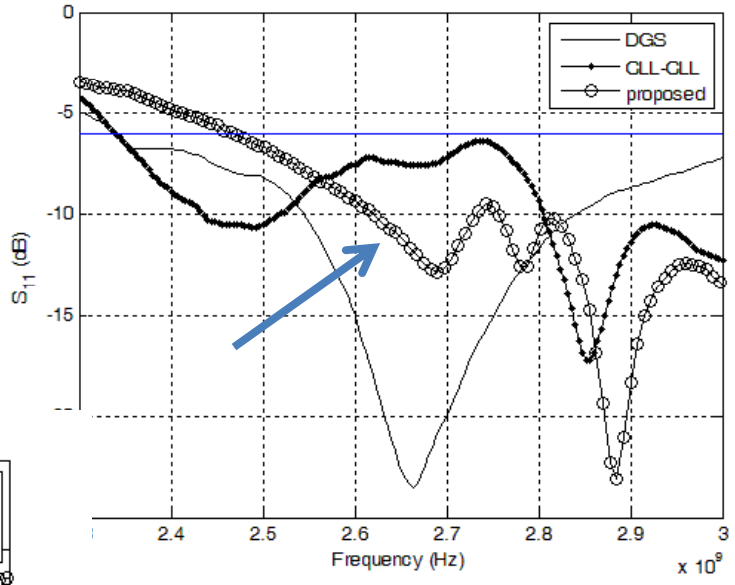


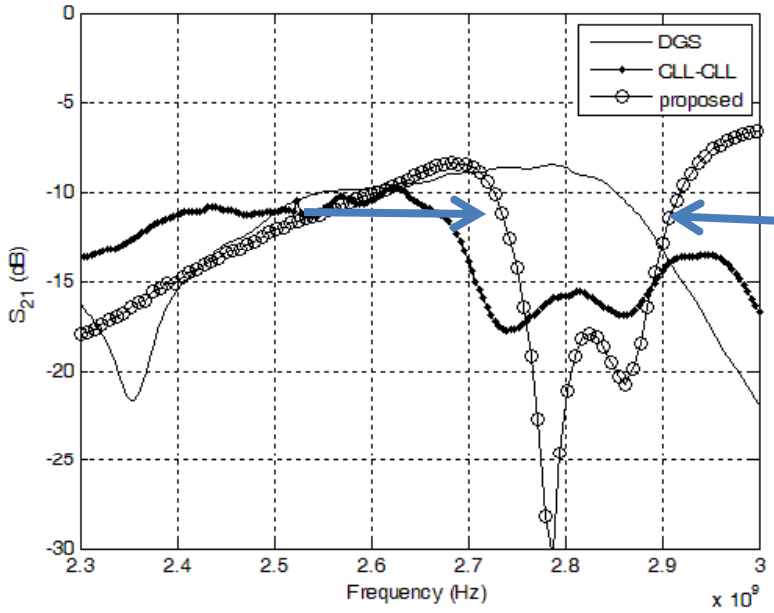




Measured low-band S-Parameters for the proposed Dual-Band Isolation Structure







Measured High-band S-Parameters for the proposed Dual-Band Isolation Structure

SUMMARY TABLE

METRIC		ANTANNA			
		REFERENCE	DGS	CLL-CLL	CLL-SRR
Operating Bands (GHz)	L H	**0.762 - 0.792** **2.465 - 2.61**	**0.805 - 0.825** **2.45 – 3.1**	**0.827 – 0.853** **2.3 – 3.3**	**0.868 – 0.897** **2.46 – 3.3**
Isolation (dB)	L H	**6** **7**	**17** **10**	**18** **15**	**9** **18**
Efficiency (%)	L H	28-37 64-74	38-43 65-68	25-32 40-70	20-35 45-60
Gain Max (dBi)	L H	**-4** **2.5**	**-0.5** **1.86**	**-2** **6**	0 5.2

L: Low Band
H: High Band
Bold face is measured

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- **Conclusions**

CONCLUSIONS

- **Coming up with novel multi-band printed antenna geometries for user handsets is very important.**
- **Targeting the lower band of operation of the 4G wireless standard with efficient, cheap and easy to integrate MIMO antenna systems is one of the major challenges nowadays.**
- **Improving the isolation between adjacent antennas is still a challenge and depends on the type of antennas used.**

- **Multiband isolation enhancement can be achieved using combinations of single band ones.**
- **Isolation methods affect the antenna system performance differently, and thus the most effective mechanism needs to be carefully chosen.**

THANK YOU!

QUESTIONS!

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